Annals of Tropical Research 22:[1&2]:105-118 (2000)
ViSCA, Leyte, Philippines

Effects of temperature on drying rates and sensory qualities of sweetened maturing coconut meat (coco-crisps)

Lemuel M. Diamante[1], Jesebel P. Rosillo[1] and Remberto Patindol[2]

[1]*Department of Agricultural Chemistry and Food Science, Visayas State College of Agriculture, Baybay 6521-A Leyte, Philippines.*
[2]*Department of Agricultural Engineering and Applied Mathematics, Visayas State College of Agriculture, Baybay 6521-A Leyte, Philippines*

ABSTRACT

Diamante, L.M., J. Rosillo and R. Patindol. 2000. Effect of temperature on drying rates and sensory qualities of sweetened maturing coconut meat (coco-crisps). *Ann. Trop. Res.* 22[1&2]:105-118.

This study was conducted to determine the effect of temperature on the drying rates and sensory qualities of sweetened maturing coconut meat called coco-crisps at ambient humidity, constant air velocity and tray density.

The drying of sweetened maturing coconut meat at different temperatures (62-90 °C) using an air velocity of 0.25 m/s and a tray density of one layer deep consisted of a constant rate period (CRP) and two stages of the falling rate period (FRP). The CRP drying rates and FRP drying coefficient in both stages increased with temperature. The first stage FRP was faster than the second stage. The activation energy for drying of the product in the first stage FRP was 18.65 KJ/mole and was in the same range as other biological products like casein curd, potatoes and sugar beets. The activation energy for drying of the product in the second stage FRP was about three times higher than in the first stage FRP.

The color acceptability of the product dried down to a moisture content of 3% (dry basis) using drying temperatures of 64 and 80°C were not significantly different from each other and were better than the product dried at 96°C. The samples dried at 64 and 80°C remained white in color while the one dried at 96°C turned light brown in color. However, the product dried at 96°C was better than the other two products based on texture and overall acceptability.

Keywords: constant rate period. drying temperature. drying rates. falling rate period. sensory qualities. sweetened coconut meat.

Correspondence: L.M. Diamante. Address: Department of Agricultural Chemistry and Food Science, Visayas State College Of Agriculture, Baybay, Leyte 6521-A Philippines. Tel. (035) 335-2619 E-mail: lmdiamante@eudoramail.com

INTRODUCTION

The economic situation of many coconut-exporting countries, including the Philippines, has drastically been affected by the continuing fluctuation of coconut oil price in the world market for the past several years. As a result, development of new food products from coconut has been carried out to diversify its utilization through processing of coconut into high valued, non-traditional food products for domestic and export markets. One method of processing coconuts into food products is by dehydrating sweetened coconut meat at various degrees of maturity (from young to mature coconuts).

One of the dehydrated food products developed from coconut is called coco-crisps, a dried crispy product from a maturing coconut meat (9-10 month old) meat. Coco-crisps has white color, leaves no fibrous texture and has the right crispiness. Its processing involves nut husking, meat removal, meat slicing, blanching in boiling water, cooking in sugar syrup, soaking in syrup overnight, draining, drying and packaging (Truong *et al.,* 1984). The drying process of coco-crisps is a very important step in terms of both process economics and product acceptability.

Previous research showed that high drying temperatures increased drying rates of coconut meat resulting in shorter drying times (Bimbenet *et al.,* 1985; Lozada, 1978). The rate and temperature of drying have a substantial effect on the texture of foods. Heat does not only vaporizes water during drying but also causes the loss of volatile components from the food. Drying also changes the surface characteristics of the food hence, alters the reflectivity and color. In general, rapid drying, longer drying times and high temperatures cause greater changes than moderate length of drying and lower temperatures, respectively (Johnson and Peterson, 1974). Holdsworth (1971) reported that structure and composition of raw materials, shrinkage during drying and loss of volatile components and browning reaction are the important aspects determining organoleptic properties during dehydration of food products. The sensory qualities of food products dried at high temperature may be affected (Desrosier, 1970).

This study was conducted to determine the effect of temperature on the drying rates and sensory qualities of sweetened maturing coconut meat meat called coco-crisps at ambient humidity, constant air velocity and tray density.

MATERIALS AND METHODS

Coco-crisps processing

About nine-month old coconuts of the Baybay Tall cultivar were obtained from the experimental fields of the Regional Coconut Research Center (RCRC), ViSCA, Baybay, Leyte. The nuts were husked, split and shelled. The coconut meat was sliced into 0.7-1.2 mm thick slices using a mechanical slicer, blanched in boiling water for 15 minutes, drained and cooked in 50% sugar syrup for about 15 minutes and soaked in syrup overnight. The drained samples were used in the drying experiments.

Electric cabinet dryer

The electric cabinet dryer used in the study is shown in Fig.1. The dryer consists of a blowing section, heating section, flow straightening and mixing section and drying chamber. The blowing section consists of a centrifugal fan driven by a 0.377 kw (½ hp) motor. The amount of air flow admitted into the dryer can be varied by using air baffles at the inlet section. The heating section consists of four 1.5 kw heaters with variable controls. The flow straightening and mixing section consists of 0.30 m long, 0.025m by 0.025 m square channels made of GI sheet. The drying tray is connected to an electronic weighing balance and suspended inside the drying chamber. During the drying experiments, the upper exhaust window was fully opened while the bottom window was fully closed.

Moisture content determination

The moisture content of the samples were determined using the air oven method at 105 ± 3°C for at least 15 hours without grinding the samples. The dried samples were cooled in a desiccator with selica gel before weighing. An electronic weighing balance with an accuracy of 0.0001 g was used for all measurements (Mettler AE 200). Moisture content determination was done at least in triplicate. The moisture content of the samples was calculated on a percent dry basis.

Drying curve determination

The dryer was stabilized for one hour at the required conditions. The air velocity of the drying air was fixed at the lower air velocity of 0.25 m/s in

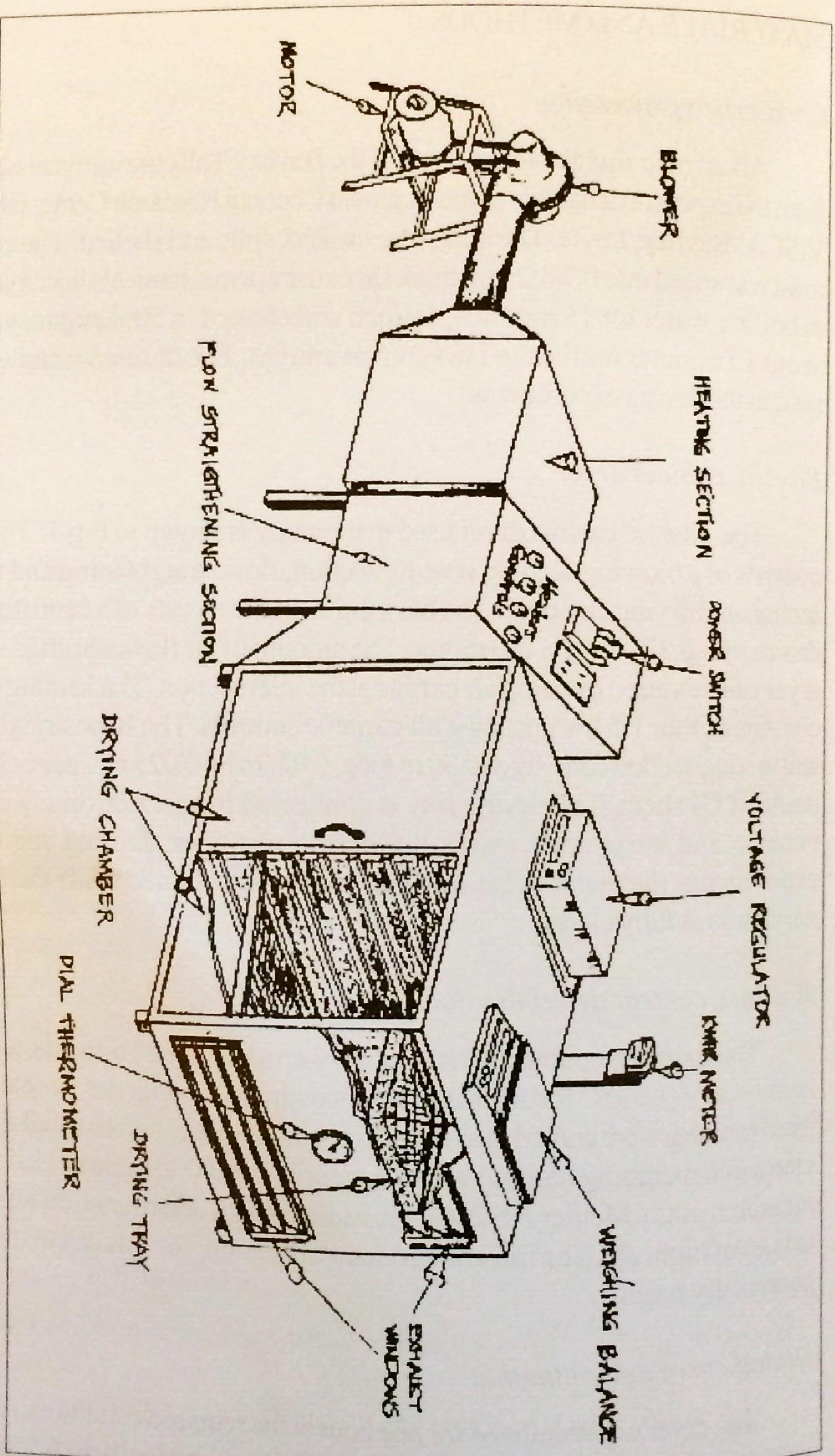

Figure 1. Electric cabinet dryer (*not drawn to scale*)

order to attain the high drying temperature needed in the experiments. The air humidity was at ambient conditions and was determined via the dry bulb and wet bulb temperatures of the air using a fan-driven psychometer during the whole duration of drying. The air humidity varied from 0.016 to 0.022 kg water/kg dry air for the whole duration of the experiments. The air velocity was determined using a velocity meter (Bacharach, Inc., USA). The drying tray weighed about one kilogram and was made of 0.0375m by 0.0375 m angle bar for its frame and aluminum screen for its flooring and cover. The area of the drying tray was 0.0529m^2 (0.23m x 0.23m).

The effect of the moving air to the instantaneous weight of the sample during weighing was minimized by using a heavy drying tray and low air velocity. The tray was connected to an electronic weighing balance (Mettler Toledo PB1501) and suspended in the drying chamber. The electronic weighing balance also had a compensator for dynamic weighing (i.e. movement of samples while weighing). The drying tray was tared prior to every experiment so that only the weight of the samples was monitored. Drying was started and the change in weight of the samples was determined using the dynamic weighing facility of the balance. The experiment was run until the weight of the sample was less than 0.1 g after 30 minutes of elapsed time. The moisture content of the dried sample was determined using the procedure mentioned above.

Similar procedure used by Diamante and Munro (1994) for obtaining the drying curves of sweetpotato slices at different drying conditions was followed. The weight of the dry solids of the sample for a given run was determined from the average moisture content and the weight of the sample at the end of drying. Using this data,the weight of the sample for a given period of the time was converted into moisture content. Plots on moisture content versus time (drying curve) were plotted for each drying run.

Drying data processing

Using the obtained drying curve, the drying rate was determined by taking the slope of the drying curve at each data point (drying rate) and plotting it against the corresponding moisture content yielding the drying rate curve (Diamante *et al.*, 1992).

The drying data were analyzed using the linear and logarithmic models mentioned by Diamante *et al.* (1992) in their study on drying of casein curd. By taking a linear regression on the initial part of the drying curve,

$$M = a + bt \tag{1}$$

where:

M = moisture content of sample at time, t
a = intercept of the regression line
b = slope of the regression line, t = constant rate period drying rate

when the coefficient of determination (r^2) of the regression is above 0.90, this strongly suggests that a constant rate period (CRP) exists. Otherwise, there is none.

The logarithmic model is in the form:

$$dM/dt = c + FM \tag{2}$$

where:

dM/dt = drying rate of the sample
c = intercept of the regression line
F = slope of the regression line, M = falling rate period drying coefficient

Again when the r^2 of the regression is above 0.90, this strongly suggests that a falling rate period (FRP) exists. Otherwise, there is none.

The obtained CRP drying rates were related to drying temperature. In cases where there was no trend found, the average value of the CRP drying rate was used for the range of conditions used. The FRP drying coefficient was related to the drying temperature using an Arrhenius type equation shown below:

$$\ln F = g + h(1/T_k) \tag{3}$$

where:

g = intercept of the Arrhenius plot
h = slope of the Arrhenius plot
T_k = absolute temperature (°K)

From the slope of the Arrhenius plot, the activation energy for drying in the FRP can be determined using the equation:

$$E_a = -h R \tag{4}$$

where:

E_a = activation energy for drying in the FRP (J/mole)

R = universal gas constant = 8.314 J/ [mole.°K]

Sensory evaluation of the dried products

Samples of the dried products at different temperatures were subjected to sensory evaluation using at least 20 semi-trained panelists composed mostly of students, faculty and staff of the DAC-FS, ViSCA using a 9-point Hedonic scale in terms of their color, texture and overall acceptability scores. The Friedman Two Way Analysis of Variance by Ranks was used in analyzing the results of the sensory evaluation by converting to ranks the color, texture and overall acceptability scores (Siegel and Castellan, 1988).

RESULTS AND DISCUSSION

Effect of temperature on drying of sweetened maturing coconut meat

Drying of sweetened maturing coconut meat at the same air velocity (0.25 m/s) and tray density (one layer deep) but at different temperatures were carried out. Representative drying curves of the products at 62, 70, 83, and 96°C are shown in Figure 2. Results indicate that the higher the temperature the faster the drying. To dry the product down to a final moisture content of 5% dry basis, the drying time at 96°C was about 40 minutes, at 83°C about 90 minutes, at 70°C about 160 minutes and at 62°C about 290 minutes. The results are in agreement with the observations of Cardenas (1968) and Palmer (1968) as cited by Lozada (1978) for drying mature coconuts at different drying temperatures.

The drying rate curves of sweetened maturing coconut meat at different drying temperatures are shown in Figure 3. The higher the temperatures the higher are the drying rates of the products. The results of data analyzed using the procedure outlined earlier are shown in Table 1. The drying of sweetened maturing coconut at different temperatures consisted of a constant rate period (CRP) and a falling rate period (FRP). As expected, the CRP drying rate increased with temperature. The FRP consisted of two stages, with the first stage faster than the second stage.

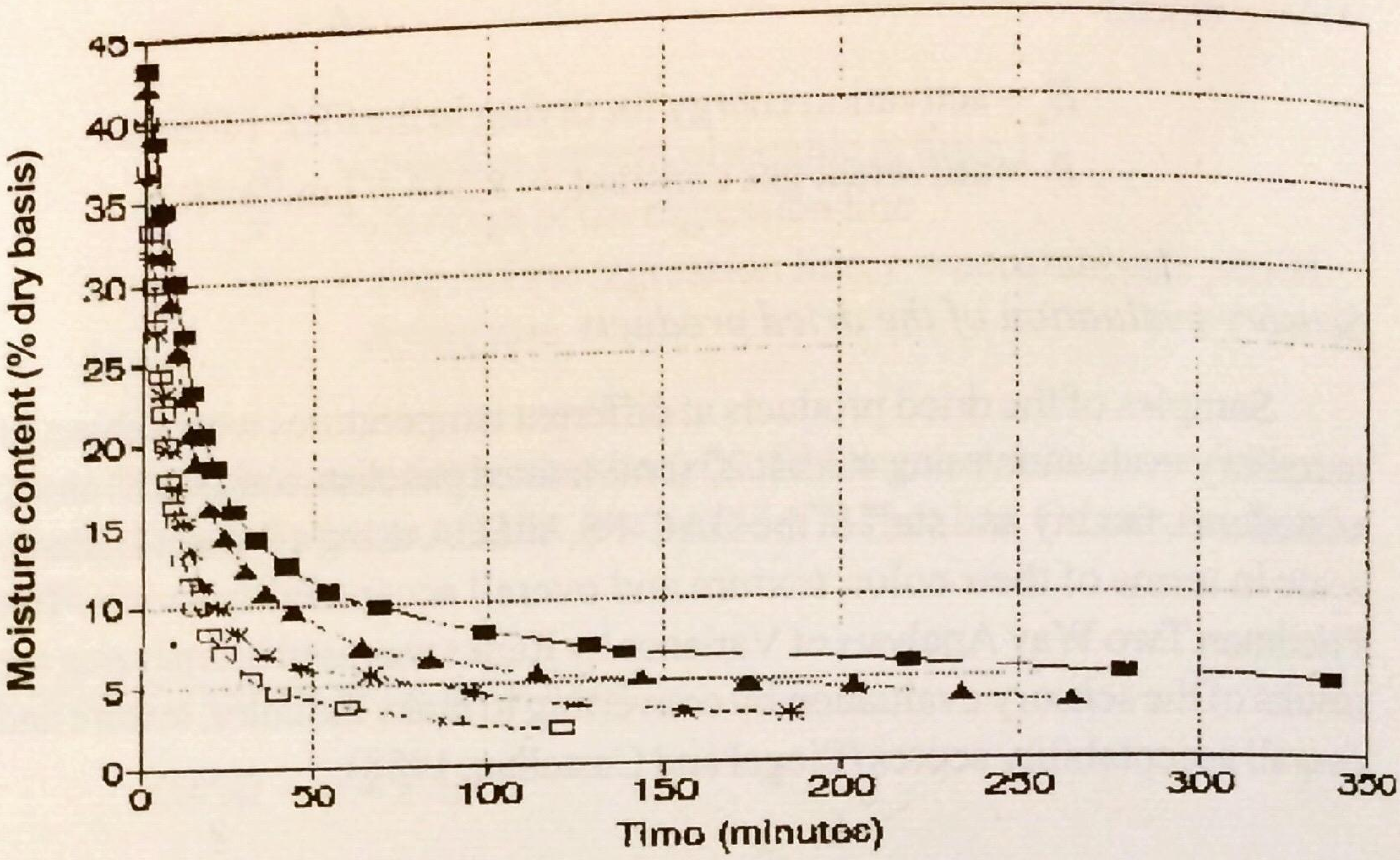

Figure 2. Drying curves of sweetened maturing coconut meat at different temperatures using an air velocity of 0.25 m/s, a tray density of one layer deep and at ambient humidity (■-62°C; ▲-70°C; ✱-83°C; □-96°C)

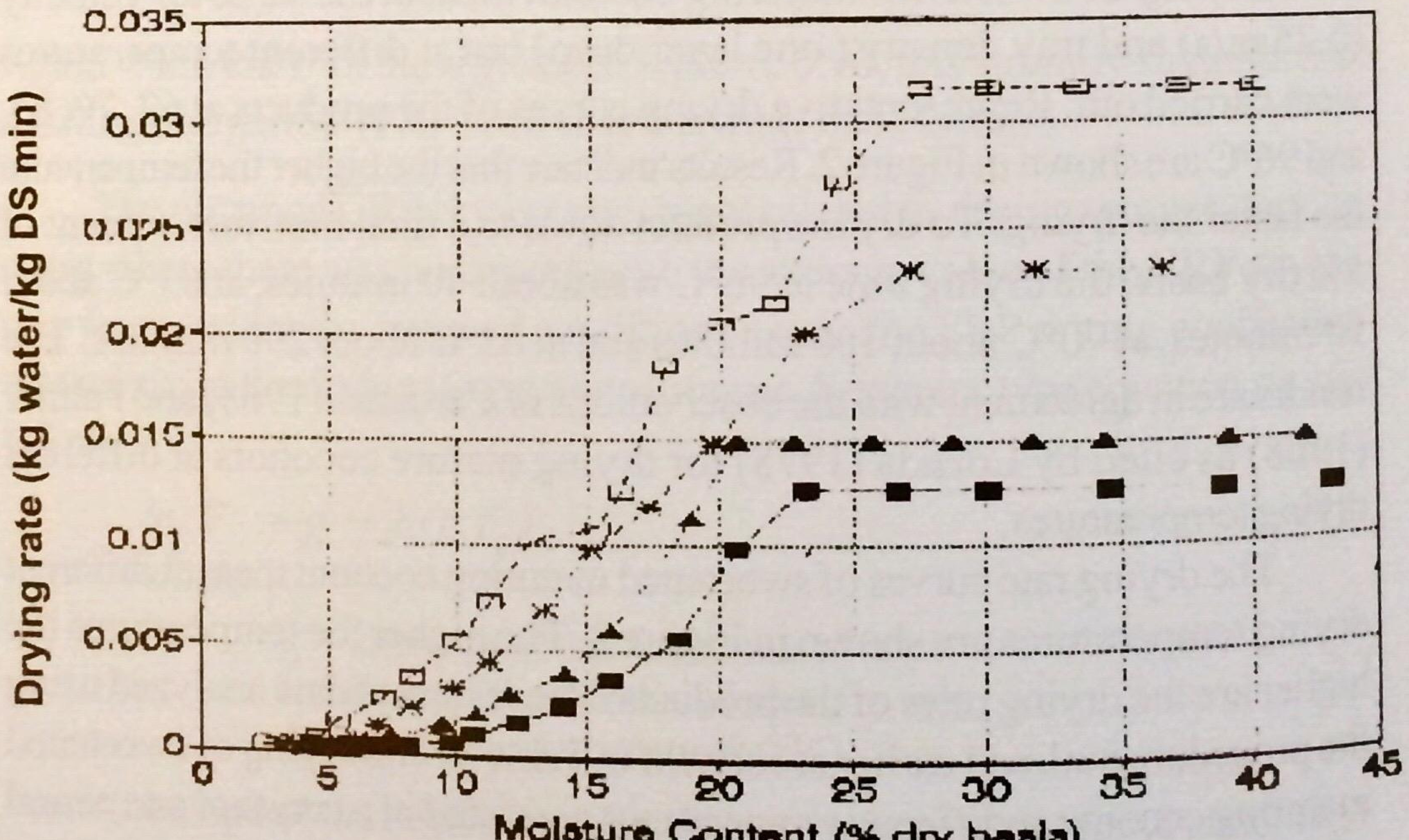

Figure 3. Drying rate curves of sweetened maturing coconut meat at different temperatures using an air velocity of 0.25 m/s, a tray density of one layer deep and at ambient humidity (■-62°C; ▲-70°C; ✱-83°C; □-96°C)

Table 1. Summary of CRP drying rates and FRP drying coefficient for sweetened maturing coconut meat dried at an air velocity of 0.25 m/s, ambient humidity, a tray density of one layer deep and different drying temperatures

Drying Temperature (°C)	CRP drying rate (kg water/[kg dry solids.min])	FRP drying coefficient (min^{-1})	
		First stage	Second stage
62	0.0127	0.0840	0.0109
64	0.0130	0.0836	0.0130
69	0.0130	0.1084	0.0181
70	0.0149	0.1117	0.0224
80	0.0236	0.1432	0.0353
83	0.0230	0.1286	0.0448
96	0.0316	0.1516	0.0670

Again as expected, the FRP drying coefficients in both stages increased with temperature. In the studies of Cardenas (1968) and Rajasekharan (1961) as cited by Lozada (1978) and also of Bimbenet *et al.* (1985) they all observed no CRP on the drying of mature coconuts. The sample in this study were maturing coconut and in addition were soaked in a sugar syrup overnight. These are probably the reasons why a CRP was observed for the product. The two stages of FRP shown by the products with the first stage faster than the second stage are in agreement with the results of Bimbenet *et al.* (1985) on drying of coconut albumen.

The CRP drying rate of sweetened maturing coconut meat using one layer deep and 0.25 m/m air velocity can be linearly related to drying temperature by the equation below:

$$(dM / dt)_C = -0.0257 + 0.000595\ T_C \quad (r^2 = 0.961) \qquad (5)$$

where:

$(dM/dt)_C$ = CRP drying rate (kg water/[kg dry solids.min])

T_C = drying temperature (°C)

The r^2 of the above regression equation was above 0.90 which suggests that there is a very strong relationship between the CRP drying rate and drying temperature. During the CRP, the rate of the evaporation of moisture is proportional to the temperature difference between air and particle surface or wet bulb temperature (Brennan *et al.*, 1976). The ambient humidity did not vary significantly during the whole duration of the drying run. Hence, the higher the air drying temperature, the higher was the moisture evaporation rate.

The effect of temperature on the FRP drying coefficients of biological products can be related using an Arrhenius type relationship (Diamante *et al.*, 1992; Yusheng and Poulsen, 1988; Chiang and Petersen, 1985; Mulet *et al.*, 1985; Vaccareza *et al.*, 1974)

Linear regression of the natural logarithm of the FRP drying coefficient (ln F) against the reciprocal of the absolute temperature ($1/T_k$) gave:

$$\ln F_1 = 4.276 - 2243.146\ 1/T_k (\ r^2 = 0.858\ ) \qquad \text{1st stage} \qquad (6)$$

$$\ln F_2 = 15.906 - 6806.986\ 1/T_k (\ r^2 = 0.978\ ) \qquad \text{2nd stage} \qquad (7)$$

where:

F_1 = first stage FRP drying coefficient (min^{-1})
F_2 = second stage FRP drying coefficient (min^{-1})

The r^2 for the regression equation in the first stage FRP was slightly low but still approached a value of 0.90. The low r^2 value was due to the very close values of the FRP drying coefficients in the first stage (Table 1). This is probably due to the influence of air humidity during the initial stage of drying which could not be kept constant from the preceding drying run to the next. Bimbenet *et al.*, (1985) also observed that air humidity affected the initial stage of drying of potato parallelepipeds. Since the first stage FRP is an intervening stage between the CRP and the second stage FRP, air humidity which greatly affects the CRP can also affect the first stage FRP. Better results may be obtained by carrying out the experiment at constant air humidity but this would be difficult to do.

However, the r^2 for the regression equation in the second stage FRP was high. The results suggest that the effect of temperature on FRP drying coefficients could be described by an Arrhenius type equation. Using the slopes of the regression equations, the activation energies for both stages of the FRP can be determined. The calculated activation energies for the first and second stage FRP for sweetened maturing coconut meat were 18.65 and 56.69 kJ/mole, respectively.

Table 2 shows the activation energies of sweetened maturing coconut meat and other biological materials which used the Arrhenius type relationship. The activation energy of the product for the first stage FRP was comparable with that of casein curd, potatoes and sugar beets but slightly higher than that

Table 2. Activation energies in the FRP of sweetened maturing coconut and other biological materials

Biological Material	Temperature Range (°C)	Activation Energy (kJ/mole) First stage	Activation Energy (kJ/mole) Second stage
Sweetened coconut meat	62-96	18.65	56.59
Carrots[a]		13.14	
Casein Curd[b]	28-132	20.63	
French-fry cut patato[c]	43-93	20.02	
Potato slabs[d]	40-70	15.43	
Sugar beets[e]	47-81	16.00	

[a]Mullet *et al.* (1985); [b]Diamante *et al.* (1992); [c]Chiang & Petersen (1985); [d]Yusheng & Poulsen (1988); [e]Vaccareza *et al.* (1974).

of carrots. All the other biological materials included in Table 2, did not have any activation energy for the second stage FRP. The activation energy for the second stage FRP of sweetened maturing coconut meat was relatively higher than from the first stage FRP. This suggests that moisture in the product during the second stage FRP was difficult to evaporate since it needed higher activation energy to force out this remaining moisture out of the product. In the FRP, rate of diffusion of moisture is proportional to product surface temperature which is dependent on the drying temperature. Therefore, the higher the drying temperature, the higher is moisture diffusion out of the product (Watson and Harper, 1991).

Effect of drying temperature on sensory qualities of the product

Samples of the dried products obtained at 64, 80 and 96°C were subjected to sensory evaluation based on color, texture and overall acceptability. Table 3 presents the mean moisture content and rank sums of the different sensory qualities of products obtained using different drying temperatures. Analysis of variance using F-test of the moisture contents of the products showed that they were not significantly different from each other (Gomez and Gomez, 1984). This means that any difference in sensory qualities cannot be attributed to the moisture content of the products.

Statistical analyses revealed that the color for the 64 and 80°C samples were significantly better than the 96°C sample at 10% level of significance. The difference in color of the products was due to browning of the product

Table 3. Mean moisture contents and rank sums for the different sensory qualities of Coco-crisps as affected by drying temperature

Drying Temperature (°C)	Moisture Content[ns] (% db)	Sensory Qualities		
		Color*	Texture**	Overall**
64	2.82	46.0 a	38.0 b	39.5 b
80	2.82	50.5 a	39.0 b	37.0 b
96	3.30	35.5 b	55.0 a	55.5 a

[ns] not significant at 5% level
* rank sums within column followed by the same letter were not significantly different from each other at 10% level
** rank sums within column followed by the same letter were not significantly different from each other at 5% level

dried at 96°C and was probably brought about by the caramelization of surface sugar due to high temperature as pointed out by Fields (1997). In addition, Fellows (1988) pointed out that drying changes the surface characteristics of foods, hence, alters the reflectivity and color. However, the 96°C product was much better than the other two products based on texture and overall acceptabilities at 5% level of significance. This is probably due to the toasting effect of high temperature on the product, which made it crispier. The results indicate that sensory qualities of the product dried at 80°C were not significantly different from sensory qualities of the product dried at 64°C.

CONCLUSION

The higher the temperature, the higher were the drying rates of sweetened maturing coconut meat resulting in shorter drying time. The drying of the product at different temperatures and at an air velocity of 0.25 m/s velocity, at ambient humidity and a tray density of one layer deep, consisted of a constant rate period (CRP) and two stages of falling rate period (FRP). The CRP drying rate and FRP drying coefficients in both stages increased with temperature. The first stage FRP was faster than the second stage. The activation energy for the second stage FRP was higher than that from the first stage FRP. Drying of sweetened maturing coconut meat at temperatures up to 80°C did not affect color, texture and overall acceptability of the dried product.

REFERENCES

BIMBENET J.J., J.D.DAUDIN and E. WOLFF. 1985. Air drying kinetics of biological particles. In: *Drying '85* (R. Toie and A.S. Mujumdar, eds.). Hemisphere Publishing Corporation. New York, pp: 178-185.

BRENNAN J.G., J.R. BUTTERS, N.D. COWELL and A.E.V. LILLY 1976. *Food Engineering Operations*. Applied Science Publishers, LTD, London.

CHIANG W.C. and J.N. PETERSEN. 1985. Thin layer air drying of french fried potatoes *Journal of Food Technology* **20**:67-78.

DESROSIER N.W. 1970. *The Technology of Food Preservation.* AVI Publishing Company, Inc., Westport, Connecticut.

DIAMANTE L.M. and P.A. MUNRO. 1994. Drying characteristics of sweetpotato slices. In: *Proceedings of the International Conference on Food Preservation and Security.* National Academy of Science and Technology. Manila, Philippines. pp: 187-199.

DIAMANTE L.M., P.A. MUNRO and M.G. WEEKS. 1992. Fluidized bed drying of a biological material (casein): Effect of drying temperature. *Paper presented during the 42nd National Convention of the Philippine Society of Agricultural Engineers (PSAE)* held at Mariano Marcos State University , Batac, Ilocos, Norte, Philippines on April 22-24, 1992.

FELLOWS P.J. 1988. *Food Processing Technology: Principles and Practice.* Ellis Horwood Ltd. London.

FIELDS M.L. 1977. *Laboratory Manual in Food Preservation*. AVI Publishing Company, Inc., Westport, Connecticut.

GOMEZ K.A. and A.A. GOMEZ. 1984. *Statistical Procedures for Agricultural Research.* John Wiley & Sons, Singapore.

HOLDSWORTH S.D. 1971. Dehydration of food products: A review. *Journal of Food Technology*. **6**:331-370.

JOHNSON A.H. and M.S. PETERSON. 1974. *Encyclopedia of Food Technology.* Volume 2. AVI Publishing Company, Inc. Westport, Connecticut.

LOZADA E.P. 1978. Principles of copra drying. In: *Proceedings on the Seminar on Methods of Copra Drying*. Philippine Coconut Authority. Diliman, Quezon, City. pp: 7-17.

MULET A., F. ROSELLO, F. PINAGA, J.V. CARBONELL and A. BERNA. 1985. Mecanismo y cinetica de secado de zanahorias con aire caliente. *Rev. Agroguim. Technol. Aliment*. **23**:369-377.

SIEGEL S. and N.J. CASTELLAN, JR. 1988. *Nonparametric Statistics for the Behavioral Sciences.* MacGraw- Hill Book Co., Singapore.

TROUNG V.D., L.S. PALOMAR, C.T. MONSERATE and R.D. LAUZON. 1984. *Coconut-based Food Products: Processing and Acceptance Studies.* Terminal Report, PCARRD- Funded, ViSCA, Leyte

VACCAREZZA L.M., J.L. LOMBARDI, and J. Chirife. 1974. Kinetics of moisture movement during air drying of sugar beet root. *Journal of Food Technology.* **9**: 317-327.

WATSON E. L. and J.G. HARPER. 1991. *Elements of Food Engineering.* Van Nostrand Reinhold Company, New York.

YUSHENG Z. and K.S. POULSEN. 1988. Diffusion in potato drying. *Journal of Food Engineering.* 7:249-262.